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Chapter 1.0

Chapter 1.0
CASTNet Measurements

A national monitoring network was mandated as part of the 1990 Clean Air Act Amendments to determine the effectiveness of future emission reductions. The U.S. Environmental Protection Agency (EPA) established the Clean Air Status and Trends Network (CASTNet) to provide data to determine relationships between emissions, air quality, deposition, and ecological effects. The basic tenets of CASTNet are to define the spatial distribution of pollutants, detect and quantify trends in pollutants, implement monitoring in cooperation with other agencies and organizations, and implement monitoring to fill gaps in monitoring coverage. This report summarizes the CASTNet monitoring activities and the resulting concentration data for 1998.

Introduction

Atmospheric deposition takes place via two pathways: wet deposition and dry deposition. Wet deposition is the result of precipitation events (rain, snow, etc.) which remove particles and gases from the atmosphere. Dry deposition is the transfer of particles and gases to the landscape in the absence of precipitation. While wet deposition rates of acidic species across the United States have been well documented over the last 20 years, comparable information has been unavailable for dry deposition rates. However, CASTNet is now providing estimates of dry deposition at sites across the U.S.

In 1986, EPA established the National Dry Deposition Network (NDDN). The objective of the NDDN was to obtain field data at approximately 50 sites throughout the United States to establish patterns and trends of dry deposition. The approach adopted by the NDDN was to estimate dry deposition using measured air pollutant concentrations and modeled deposition velocities estimated from meteorological, land use, and site characteristic data.

Passage of the Clean Air Act Amendments (CAAA) in 1990 required implementation of a national network to: 1) monitor the status and trends of air emissions, pollutant deposition, and air quality; 2) determine the effects of emissions on water quality, forests, and other sensitive ecosystems; and 3) assess the effectiveness of emission reduction requirements through operation of a long-term monitoring program. In response to the requirements of the CAAA, EPA, in coordination with the National Oceanic and Atmospheric Administration (NOAA), created CASTNet. CASTNet became operational in mid-1991, and the NDDN was incorporated into CASTNet at that time.

EPA contracted Environmental Science & Engineering, Inc., (ESE) to establish and operate CASTNet. The primary goals of CASTNet are to establish an effective monitoring and assessment network to determine the status and trends of air pollution levels and their environmental effects, and to develop a scientific database to improve understanding of sources and effects for policy considerations. In meeting these goals, an important objective of CASTNet is to establish patterns and trends of dry deposition.

As with the NDDN, CASTNet estimates dry deposition using measured air pollutant concentrations and deposition velocities (V_d) estimated from meteorological, land use, and site characteristic data. The Multi-Layer Model (MLM) currently used for dry deposition flux simulations has been described recently by Myers *et al.*, (1998). In 1998 CASTNet included measurements of precipitation chemistry, ozone (O_3) concentrations, aerosols and visibility-related parameters.

The National Park Service (NPS) joined CASTNet in 1994 by assuming operations at 19 sites and has subsequently added more sites. In 1998, NPS operated 26 sites. The measurements at NPS sites are consistent with EPA sites and are merged into a single database that is delivered quarterly to EPA.

This report summarizes results of CASTNet monitoring activities for 1998. Annual and quarterly average concentration data for atmospheric sulfur and nitrogen species are presented, and temporal variability is described. O_3 data are also presented for 1998. Concentrations of fine mass for 1998 and time series from 1994 through 1998 are also presented. Estimates of dry deposition are not presented in this report because EPA is currently reviewing the MLM.

Network Description

The status of the CASTNet network, as of December 1998, is shown in Figure 1-1. Seventy-nine primarily rural sites, with 26 west of the Mississippi, were operational. Seventy-four* of the 79 sites were equipped with filter packs for measurement of pollutant concentrations and estimation of deposition rates. Two dry deposition sites included collocated sampling systems for determining network precision.

CASTNet included eight sites that take visibility-related measurements, including aerosol filter packs. Four** of these sites also measured dry deposition, and two sites also measured optical properties of the atmosphere. The Sikes, LA site (SIK570) had collocated equipment for quality assurance purposes.

Wet deposition was measured at 19 locations, 18 of which were dry deposition sites; the Scotia Range, PA (SCR180) site was collocated with a National Acid Deposition Program (NADP) site to allow comparison with this network. Collocated precipitation sampling equipment was operated at Alhambra, IL (ALH157).

Figure 1-1. Locations of CASTNet Sites as of December 1998

* Seventy-seven sites operate dry deposition systems in August 1999.
** Six visibility sites currently include dry deposition systems.

One of the CASTNet sites is located in Egbert, Ontario, Canada. At this site, EGB181, day and night samples are collected weekly, along with a standard weekly composite CASTNet filter pack. This set-up provides the means to compare results from CASTNet with the Canadian Air and Precipitation Monitoring Network (CAPMoN).

Table 1-1 lists by state all the CASTNet sites along with the location, start date, latitude, longitude, elevation, and types of measurements. Although not indicated in Table 1-1, additional measurements are performed at several CASTNet sites by other monitoring programs (e.g., NADP/NTN, IMPROVE, and the NPS). However, these measurements are not included in the CASTNet database at this time.

Site History

Table 1-2 presents a list of discontinued sites with the reporting dates and other relevant information as in Table 1-1.

Although not indicated in Table 1-1, the NPS assumed operation of four sites in 1994 and 1995 that were originally operated by ESE (Shenandoah NP, Chiricahua NM, Glacier NP, and Grand Canyon NP). During operation by ESE, these sites were designated by 100 series numbers and with different prefixies (i.e., SHN118, CNM167, GNP168, and GCN174). Data collected at these sites are now stored in CASTNet database as 400-series site IDs.

Because of the network's size, most changes were and are implemented at the network level. Therefore, the rest of the site history is presented in the Network History section.

Network History (Dry Deposition and Ozone)

This section describes the history and operations of the CASTNet dry depositon network. The smaller visibility network is described later in Chapter 1.

Field Operations

Table 1-3 lists the major changes and/or events that may have had an impact on data quality or completeness; most of the changes occurred before 1990.

Laboratory Operations

A network history of laboratory operations is provided in Table 1-4. Fewer changes were necessary in the laboratory operations than the field operations. The analytical methods used for analysis of the filter and precipitation samples are well established methods requiring little or no modifications for analysis of CASTNet samples. Constant review and modification of training procedures for technicians and analysts, along with an interactive QA/QC program have been highly effective in maintaining the excellent quality of data produced by the ESE laboratory.

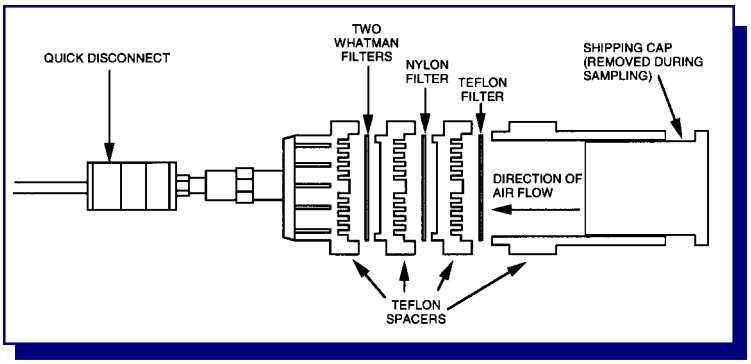
Methods

This section provides a brief overview of methods employed for CASTNet. Step-by-step protocols and additional details on these activities can be found in the CASTNet Field Operations Manual, Laboratory Operations Manual, Data Management Manual, and the Draft Quality Assurance Project Plan (ESE, 1990a, 1990b, 1998, 1999).

Field Operations

Ambient measurements for sulfur dioxide (SO_2), particulate sulfate (SO_4^{2-}), particulate nitrate (NO_3^-), nitric acid (HNO_3), particulate ammonium (NH_4^+), continuous O_3 and meteorological variables required for dry deposition calculations were performed at each CASTNet site. Meteorological variables and O_3 concentrations are recorded continuously and reported as hourly averages consisting of a minimum of nine valid 5-minute averages. Atmospheric sampling for sulfur and nitrogen species was integrated over weekly collection periods using a three-stage filter pack (Figure 1-2). In this approach, particles and selected gases were collected by passing air at a controlled flow rate through a sequence of Teflon®, nylon, and Whatman filters. The Teflon® filter removes particulate SO_4^{2-}, NO_3^-, and NH_4^+, and the nylon filter is used to remove HNO_3. The Whatman filter is a cellulose fiber base that is impregnated with potassium carbonate (K_2CO_3) and is used for removal of SO_2. In practice, a fraction (usually <20%) of ambient SO_2 is captured on the nylon filter. The nylon filter SO_2 and Whatman filter SO_2 are therefore summed to provide weekly average concentrations. The nylon filter HNO_3 is converted to NO_3^- and added to the Teflon® filter NO_3^- to provide weekly total NO_3^- concentrations.

Figure 1-2. Diagram of Three-Stage Filter Pack



Filter packs were prepared and shipped to the field weekly and exchanged at each site every Tuesday. Blank filter packs (i.e., trip blanks) were collected quarterly to evaluate contamination during shipment and handling. At 18 sites generally located more than 50 kilometers (km) from NADP/NTN sites, wet deposition samples were collected weekly using sampling protocols similar to NADP/NTN and shipped to ESE for chemical analysis.

Table 1-1. Name, Start Date, Latitude, Longitude, and Elevation of CASTNet Deposition Network Sites (Page 1 of 5)

Site ID	Site Name	Start Date	Latitude (°N)	Longitude (°W)	Elevation (m)	Deposition Filter Pack	Ozone and Meteorology[1]	Aerosol Filter Pack	Optical Scattering	Wet Deposition
Alabama										
SND152	Sand Mountain	12/27/88	34.2894	85.9704	352	•	•			
Alaska										
DEN417	Denali National Park	10/06/98	63.7233	148.9675	661	•	•			
Arizona										
CHA467	Chiricahua National Monument	04/25/89	32.0092	109.3892	1570	•	•			•
GRC474	Grand Canyon National Park	05/16/89	36.0597	112.1822	2073	•	•			
Arkansas										
CAD150	Caddo Valley	10/04/88	34.1792	93.0989	71	•	•			
California										
DEV412	Death Valley National Monument	02/21/95	36.5092	116.8481	125	•	•			
JOT403	Joshua Tree National Monument	02/16/95	34.0714	116.3906	1244	•	•			
LAV410	Lassen Volcanoes National Park	07/25/95	40.5403	121.5764	1756	•	•			
PIN414	Pinnacles National Monument	05/16/95	36.4850	121.1556	335	•	•			
SEK402	Sequoia National Park	02/04/97	36.4292	118.7625	1225	•	•			
YOS404	Yosemite National Park	09/25/95	37.7133	119.7061	1605	•	•			
Colorado										
GTH161	Gothic	05/16/89	38.9573	106.9854	2926	•	•			•
MEV405	Mesa Verde National Park	01/10/95	37.1983	108.4903	2165	•	•			
ROM406	Rocky Mountain National Park	12/20/94	40.2778	105.5453	2743	•	•			
Connecticut										
ABT147	Abington	12/28/93	41.8408	72.0111	209	•	•			•
Florida										
EVE419	Everglades National Park	10/06/98	25.3883	80.6833	2	•	•			
SUM156	Sumatra	12/28/88	30.1065	84.9938	14	•	•			•

Table 1-1. Name, Start Date, Latitude, Longitude, and Elevation of CASTNet Deposition Network Sites (Page 2 of 5)

Site ID	Site Name	Start Date	Latitude (°N)	Longitude (°W)	Elevation (m)	Deposition Filter Pack	Ozone and Meteorology[1]	Aerosol Filter Pack	Optical Scattering	Wet Deposition
Georgia										
GAS153	Georgia Station	06/28/88	33.1792	84.4053	270	•	•			
Illinois										
ALH157	Alhambra	06/28/88	38.8689	89.6219	164	•	•	◦		•
BVL130/530	Bondville	02/09/88	40.0514	88.3719	212	•	•			
STK138	Stockton	12/28/93	42.2869	90.0000	274	•	•			
Indiana										
LIV573	Livonia	10/07/93	38.5347	86.2608	299		◦	•		
SAL133	Salamonie Reservoir	06/28/88	40.8164	85.6608	250	•				
VIN140	Vincennes	08/04/87	38.7406	87.4844	134	•	•			
Kentucky										
CDZ571	Cadiz	10/01/93	36.7854	87.8504	189	•[5]	•	•	•	
CKT136	Crockett	08/24/93	37.9211	83.0658	455	•	•			
MCK131	Mackville	07/31/90	37.7044	85.0483	353	•	•			
Louisiana										
SIK570	Sikes	10/01/93	32.0585	92.4334	68		◦	•	◦	
Maine										
ACA416	Acadia National Park	12/01/98	44.3770	68.2610	152	•	•			
ASH135	Ashland	12/20/88	46.6039	68.4142	235	•	•			
HOW132	Howland	11/24/92	45.2161	68.7092	69	•	•			
Maryland										
BEL116	Beltsville	11/01/88	39.0283	76.8175	46	•	•			
BWR139	Blackwater National Wildlife Refuge	07/04/95	38.4448	76.1115	4	•	•			
Michigan										
ANA115	Ann Arbor	06/28/88	42.4164	83.9019	267	•	•			•
UVL124	Unionville	06/28/88	43.6139	83.3597	201	•	•			•
WEL149	Wellston	06/28/88	44.2236	85.8186	295	•[4]	•			
Minnesota										
VOY413	Voyageurs National Park	06/13/96	48.4128	92.8292	429	•	•			

Table 1-1. Name, Start Date, Latitude, Longitude, and Elevation of CASTNet Deposition Network Sites (Page 3 of 5)

Site ID	Site Name	Start Date	Latitude (°N)	Longitude (°W)	Elevation (m)	Deposition Filter Pack	Ozone and Meteorology[1]	Aerosol Filter Pack	Optical Scattering	Wet Deposition
Mississippi										
CVL151	Coffeeville	12/27/88	34.0028	89.7989	134	•	•			
Montana										
GLR468	Glacier National Park	12/27/88	48.5103	113.9956	976	•	•			
Nevada										
GRB411	Great Basin National Park	05/16/95	39.0053	114.2158	2060	•	•			
New Hampshire										
WST109	Woodstock	12/27/88	43.9444	71.7017	258	•	•			
New Jersey										
WSP144	Washington's Crossing	12/27/88	40.3132	74.8728	61	•	•			
New York										
CAT175	Claryville	05/10/94	41.9411	74.5514	765	•	•[2]			
CTH110/510	Connecticut Hill	09/28/87	42.4011	76.6536	515	•	•	•	°	°
North Carolina										
BFT142	Beaufort	12/28/93	34.8843	76.6213	2	•	•			•
CND125	Candor	09/25/90	35.2637	79.8370	198	•	•			•
COW137	Coweeta	11/04/87	35.0605	83.4302	686	•	•			
PNF126	Cranberry	12/27/88	36.1040	82.0448	1250	•	•			•
North Dakota										
THR422	Theodore Roosevelt National Park	10/06/98	46.8947	103.3778	850	•	•			
Ohio										
DCP114	Deer Creek State Park	09/28/88	39.6358	83.2600	267	•	•			•
LYK123	Lykens	01/10/89	40.9169	82.9981	303	•	•			•
OXF122	Oxford	08/18/87	39.5314	84.7231	284	•	•			
QAK572	Quaker City	09/28/93	39.9431	81.3378	372	•[5]	•	•	•	
Ontario										
EGB181	Egbert, Ontario	12/27/94	44.2317	79.7840	251	•[3]	•			

Table 1-1. Name, Start Date, Latitude, Longitude, and Elevation of CASTNet Deposition Network Sites (Page 4 of 5)

Site ID	Site Name	Start Date	Latitude (°N)	Longitude (°W)	Elevation (m)	Deposition Filter Pack	Ozone and Meteorology[1]	Aerosol Filter Pack	Optical Scattering	Wet Deposition
Pennsylvania										
ARE128/528	Arendtsville	06/28/88	39.9231	77.3078	269	•	•	•	°	•
KEF112	Kane Experimental Forest	01/03/89	41.5981	78.7683	622	•	•			
LRL117	Laurel Hill State Park	12/15/87	39.9883	79.2522	615	•	•			
MKG113/513	M.K. Goddard State Park	01/12/88	41.4250	80.1447	384	•	•	•		
PSU106	Penn. State University	01/06/87	40.7208	77.9319	376	•	•			
SCR180	Scotia Range	02/02/93	40.7884	77.9464	376	°	°			•
Tennessee										
ESP127	Edgar Evins State Park	03/22/88	36.0393	85.7340	302	•	•			
GRS420	Great Smoky Mountains National Park	10/06/98	35.6331	83.9422	793	•	•			
SPD111	Speedwell	06/12/89	36.4692	83.8272	361	•	•			•
Texas										
BBE401	Big Bend National Park	07/18/95	29.3053	103.1772	1052	•	•			
Utah										
CAN407	Canyonlands National Park	01/24/95	38.4583	109.8211	1814		•			
Vermont										
LYE145	Lye Brook	03/30/94	43.0504	73.0634	730	•	•[2]			•
Virgin Islands										
VII423	Virgin Islands National Park	10/06/98	18.3364	64.7964	80	•	•			
Virginia										
PED108	Prince Edward	11/03/87	37.1658	78.3068	150	•	•			•
SHN418	Shenandoah National Park	06/28/88	38.5231	78.4347	1073	•	•	°		
VPI120	Horton Station	06/02/87	37.3300	80.5573	920	•	•			
Washington										
MOR409	Mount Rainier National Park	08/29/95	46.7583	122.1222	421	•	•			
NCS415	North Cascades National Park	02/14/96	48.5397	121.4472	109	•	•			
OLY421	Olympic National Park	10/06/98	48.1181	123.4306	125	•	•			

Table 1-1. Name, Start Date, Latitude, Longitude, and Elevation of CASTNet Deposition Network Sites (Page 5 of 5)

Site ID	Site Name	Start Date	Latitude (°N)	Longitude (°W)	Elevation (m)	Deposition Filter Pack	Ozone and Meteorology[1]	Aerosol Filter Pack	Optical Scattering	Wet Deposition
West Virginia										
CDR119	Cedar Creek State Park	11/10/87	38.8794	80.8478	234	•	•			•
PAR107	Parsons	01/19/88	39.0906	79.6614	510	•	•			
Wisconsin										
PRK134	Perkinstown	09/27/88	45.2064	90.5978	472	•	•			•
Wyoming										
CNT169	Centennial	08/19/91	41.3722	106.2422	3178	•	•			
PND165	Pinedale	12/27/88	42.9214	109.7900	2388	•	•			
YEL408	Yellowstone National Park	06/26/96	44.5597	110.4006	2468	•	•			

Notes:

1 Meteorological sensors: temperature, delta temperature, relative humidity, solar radiation, vector wind speed, scalar wind speed, wind direction, sigma theta, surface wetness, and precipitation via tipping bucket rain gauge.

2 Solar-powered sites; O_3 collected seasonally.

3 Composite filter pack, day filter pack, and night filter pack.

4 Filter pack sampling at WEL149 stopped on August 4, 1998, and a search for a new site operation was initiated.

5 Began in January 1999.

100 and 500 series = EPA - Operated Sites
400 series = NPS - Operated Sites

° Indicates discontinued measurements

The dry depositon filters are analyzed for the following constituents:

Teflon® = SO_4^{2-}, NO_3^-, NH_4^+
Nylon = SO_4^{2-}, HNO_3
Whatman = SO_2

The aerosol filters are analyzed for the following constituents:

Teflon® = mass, Na, Mg, Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Ge, As, Se, Br, Rb, Sr, Y, Zr, Mo, Pd, Ag, Cd, In, Sn, Sb, Ba, La, Hg, Pb
Nylon = SO_4^{2-}, NO_3^-
Quartz = Organic Carbon, Elemental Carbon

Precipitation samples are analyzed for the following constituents:

pH, Conductivity, Ca^{2+}, Mg^{2+}, NA^+, K^+, NH_4^+, SO_4^{2-}, NO_3^-, Cl, NO_2^-, Acidity

Table 1-2. Historical Listing of Discontinued CASTNet Sites

Site ID	Site Name	Reporting Dates	Latitude (°N)	Longitude (°W)	Elevation (m)	Deposition Filter Pack	Ozone and Meteorology	Wet Deposition
Idaho								
RCK163	Reynolds Creek	05/89-09/93	43.21	116.75	1198	•	•	
Illinois								
ANL146	Argonne	07/87-04/93	41.70	88.00	229	•	•	
Kentucky								
LCW121	Lilley Cornett Woods	01/88-12/93	37.13	82.99	335	•	•	
PBF129	Perryville	08/87-07/90	37.68	84.97	279	•	•	
Nevada								
SAV164	Saval Ranch	05/89-09/93	41.29	115.86	1873	•	•	
New Hampshire								
WST183	Woodstock (ridge site)	06/91-11/94	43.94	71.70	258	•	•	
New York								
WFM105	Whiteface Mountain	01/87-03/93	44.39	73.86	570	•	•	
WPA103	West Point-A	01/87-09/88	41.35	74.05	203	•	•	
WPB104	West Point-B	01/87-09/93	41.35	74.05	203	•	•	
North Carolina								
COW182	Coweeta (ridge site)	06/91-08/94	35.05	83.44	686	•	•	
RTP101	Research Triangle Park	01/87-12/89	35.91	78.88	94	•	•	
Tennessee								
ONL102	Oak Ridge	01/87-12/88	35.96	84.29	341	•	•	
Utah								
UIN162	Uinta	05/89-09/93	40.55	110.32	2502	•	•	•

Table 1-3. Network History of Field Operations

First Quarter 1987

Changed Campbell data acquisition system (DAS) to Sumx DAS.
Changed Dasibi to Teco O_3 analyzer.
Added new tilt-down dry deposition towers.

Second Quarter 1987

Changed Sumx to Odessa/PC DAS.
Strip chart backup DAS replaced with Odessa DAS.

Third Quarter 1987

Provided extra caps for filter packs onsite.
Provided gloves for operator to use for filter changes.
Increased shelter temperature to 77 degrees Fahrenheit.
Added insulation to O_3 and flow samples lines.
Incorporated magnetic declination for reporting wind direction.
Added condensation knock-out bottles to sample train.
Replaced prototype relative humidity sensors with Climatronics sensors.

Fourth Quarter 1987

Improved Site Status Report Form and operator training to minimize data loss.
Began using automated polling as primary data source.
Added source flag to database.

Second Quarter 1988

Began use of RM Young meteorological systems.
Began adding lightning protection circuits to incoming signals.

Third Quarter 1988

Installed Odessa firmware modification for O_3 autocals.
Field technicians supplied with spare parts kits.
Installed Odessa solar radiation translators at RM Young sites.

Fourth Quarter 1988

Began inhouse repair of Climatronics solar radiation systems.
Changed some Climatronics relative humidity sensors to Rotronic relative humidity sensors.

First Quarter 1989

Added dichotomous PM_{10} samplers at sites: PAR107 (2), WST109, VPI120, BVL130, and COW137.
Initiated wet deposition sampling using Andersen/Belfort equipment.

Second Quarter 1989

Added Vaisala wetness sensors.
Added scalar wind speed parameter to DAS.

Third Quarter 1989

Added rotometers to filter pack sample train.
Changed RM Young relative humidity sensor from mechanically aspirated shields to naturally aspirated shields.
Replaced Odessa solar radiation translators with RM Young translators at RM Young sites.

Fourth Quarter 1989

Initiated problem detection, resolution, and reporting database.

First Quarter 1990

Switched day/night sampling to composite sampling.
Ended dichotomous sampling at designated sites.

First Quarter 1991

Added blower status switches to mechanically aspirated shields at RM Young sites.

First Quarter 1992

Tested replacement of nylon filter with Whatman filter for HNO_3 at collocated sites.

First Quarter 1994

Changed relative humidity sensors at Climatronics sites from Rotronic sensors back to Climatronics sensors.
Replaced Vaisala wetness sensors with RM Young wetness sensors.
Began replacing Andersen wet/dry collectors with Aerochem Metrics wet/dry collector.

Fourth Quarter 1995

Began decanting wet samples to bottles instead of shipping samples in buckets.
Network operation reduced to 15 sites (13 eastern and 2 western) at the request of EPA: WST109, CAT175, EGB181, PSU106, ARE128, PAR107, COW137, BFT142, SUM156, OXF122, VIN140, PRK134, SHN418, GTH161, CNT169. During the temporary shut-down, NPS operated the following sites: BBE401, CAN407, CHA467, DEV412, GLR468, GRB411, GRC474, JOT403, LAV410 MEV405, MOR409, NCS415, PIN414, ROM406,YOS404

Second Quarter 1996

Replaced DAS firmware to eliminate leap year error.
Reactivation of full network.

First and Second Quarter 1998

All site ozone analyzers were updated to provide ozone test gas concentrations through the complete sample train for the purpose of QC precision checks.

Third Quarter 1998

Site calibration and maintenance visits were reduced from quarterly to once every six months.

Third and Fourth Quarter 1998

Six of the remaining eight wet deposition sites with Andersen wet/dry collectors were upgraded with Aerochem Metrics wet/dry collectors. The last two sites, CHA467 and PRK134, were upgraded in January 1999.

Filter pack sampling and O_3 measurements were performed at 10 meters (m) using a tilt-down aluminum tower (Aluma Tower, Inc.). Filter pack flow was maintained at 1.50 liters per minute (Lpm) at eastern sites and 3.00 Lpm at western sites, for standard conditions of 25 degrees Celsius (°C) and 760 millimeters of mercury (mmHg) with a mass flow controller (MFC). Wet deposition samples were collected in precleaned polyethylene buckets using an Andersen Model APS or an Aerochem

Table 1-4. Summary of Network History for Laboratory Operations

Date	Event
July 1988	
	Began analysis of cations (NH_4^+, Ca^{2+}, Mg^{2+}, Na^+ and K^+) from Teflon® filter.
January 1989	
	Began analysis of wet deposition samples.
October - December 1989	
	Last quarter for analysis of day and night filters. Discontinued analysis of cations on filters.
October 1989	
	Stopped sonication of Nylon filters (shaking only).
January 1990	
	Added 0.05% H_2O_2 to Nylon filter extraction solution.
January 1993	
	Added 0.03 N HCl to Whatman filter extraction solution.
April 1995	
	Stopped analysis of K^+ via AA. Started using 3000 Perkin-Elmer Dual View ICAP for analysis of Ca^{2+}, Na^+, Mg^{2+},and K^+.
July 1997	
	Transferred calculation or final atmospheric concentrations to the DMC.
October 1997	
	Suspected change in composition or preparation of Teflon® filters by manufacturer.
August 1998	
	Changed manufacturer of Teflon® filters from Gelman to Whatman.

Metrics precipitation sampler. Buckets were placed on the sampler on Tuesday and removed, whether or not rainfall had occurred, the following Tuesday. Buckets were weighed in the field, decanted to a polyethylene bottle, sealed, and shipped to ESE for chemical analysis. The precipitation amount (inches) was also monitored at wet deposition sites. The chemical analysis of the precipitation samples was turned over to NADP/NTN in February 1999.

The CASTNet continuous measurements are archived as hourly averages and are indexed at the end of each hour (i.e., hour 2300 references the measurement over the hour 2200 through 2300). The discrete filter and precipitation chemistry data are archived as weekly averages and are referenced by start date (and time). CASTNet generally uses a 75% data completeness criterion to constitute a valid sample, e.g., 75% of possible hourly flow values are required to constitute a valid weekly average concentration from an exposed filter. Procedures to aggregate weekly data to obtain quarterly and annual measurements are discussed in Chapter 2.0.

Ambient O_3 concentrations were measured via ultraviolet (UV) absorbance with a Thermo-Environmental Model 49-103 analyzer. Zero, precision [60 parts per billion (ppb)], and span (400 ppb) checks of the O_3 analyzer were performed every Sunday using an internal O_3 generator. Although precision and accuracy for CASTNet O_3 data (see Chapter 6.0) meet data quality objectives, CASTNet quality assurance procedures for O_3 do not strictly conform to the EPA requirements for State and Local Monitoring Stations (SLAMS) monitoring (40 CFR Part 58, Appendix A).

In addition, various observations were periodically made at CASTNet sites to support model calculations of dry deposition. Site operators recorded surface conditions (e.g., dew, frost, snow) and vegetation status weekly. Vegetation status and land-use information were used to define the distribution and condition of plant species around each site that could influence deposition rates for gases and particles. Vegetation data were obtained to track evolution of the dominant plant canopy, from leaf emergence (or germination) to senescence (or harvesting). During the second half of 1998, ESE calibrators updated information on major plant species and land-use classifications within 1.0 km of each site.

Additional land-use data were obtained by digitization and analysis of aerial photographs obtained from the U.S. Geological Survey (USGS) National Cartographic Information Center in Reston, VA. Photographs were interpreted according to procedures described by Anderson *et al.* (1978).

Leaf area index (LAI) measurements were taken at all CASTNet sites during the summers of 1991 and 1992, and at most of the NPS sites during the summer of 1997. LAI is the one-sided leaf area of the plant canopy per unit area of ground at full leaf emergence and has been shown to play an important role in atmosphere-canopy exchange processes (McMillen, 1990). LAI was measured using an LAI-2000 Plant Canopy Analyzer manufactured by Li-Cor (Lincoln, NE). The LAI-2000 makes indirect (i.e., nondestructive) estimates of LAI from simultaneous measurements of light interception by the plant canopy at five angles of inclination (Li-Cor, 1989).

All field equipment was subjected to quarterly inspections and multipoint calibrations during the first half of 1998 and semi-annually thereafter, using standards traceable to the National Institute of Standards and Technology (NIST). Results of field calibrations were used to assess sensor

accuracy and flag, adjust, or invalidate field data. In addition, independent audits were performed annually by Air Resource Specialists, Inc. (ARS). Results of 1998 QA activities are discussed in Chapter 6.0.

Laboratory Operations

Filter pack samples were loaded, shipped, received, extracted, and analyzed by ESE personnel at the Gainesville, FL laboratory. Filter packs contained three types of filters in sequence: a Teflon® filter for collection of aerosols, a nylon filter for collection of HNO_3, and dual K_2CO_3-impregnated cellulose filters for collection of SO_2.

Following receipt from the field, exposed filters and blanks were extracted and then analyzed for SO_4^{2-} and NO_3^- by micromembrane-suppressed ion chromatography (IC). Teflon® filter extracts were also analyzed for NH_4^+ by the automated indophenol method using a TRAACS-800 Autoanalyzer system. All analyses were completed within 72 hours of filter extraction. Figure 1-3 depicts the sequence of laboratory operations for filter pack sample analyses.

Wet deposition samples were filtered and then analyzed for pH, conductivity, acidity, sodium (Na^+), potassium (K^+), NH_4^+, calcium (Ca^{2+}), magnesium (Mg^{2+}), chloride (Cl^-), nitrite (NO_2^-), NO_3^-, and SO_4^{2-}. Analysis of NH_4^+ and anions was performed as described previously for filter pack samples. Analysis of Na^+, Mg^{2+}, Ca^{2+} and K^+ was performed with a Perkin-Elmer ICP-PE 3000 DV inductively coupled argon plasma (ICAP) emission spectrometer. Acidity was determined via titration to approximately pH of 8.3. Figure 1-4 depicts the sequence of laboratory operations for wet deposition sample analyses.

Results of all valid analyses were stored in the laboratory data management system [Chemistry Laboratory Analysis and Scheduling System (CLASS™)]. Atmospheric concentrations were calculated (based on volume of air sampled) following validation of hourly flow data.

Data Management

This section summarizes the overall data management system used for CASTNet. The flow of data is shown in Figure 1-5.

Field Data

Field data, or continuous data, were handled by the Data Management Center (DMC). The DMC activities consisted of four major operations: data acquisition, data validation, model operation, and transmittal to EPA. These activities are described briefly in this subsection. Details on data management and operation of the MLM are provided in the CASTNet Data Management Manual (ESE, 1998, in press), and the draft QAPP (ESE, 1999). The MLM is discussed later in this section.

The data acquisition process stresses multiple levels of redundancy to minimize data loss. The primary mode of data acquisition from the field was via telephone modem. The sites were automatically polled daily using

Figure 1-3. Flowchart of Laboratory Operations for Filter Pack Analyses

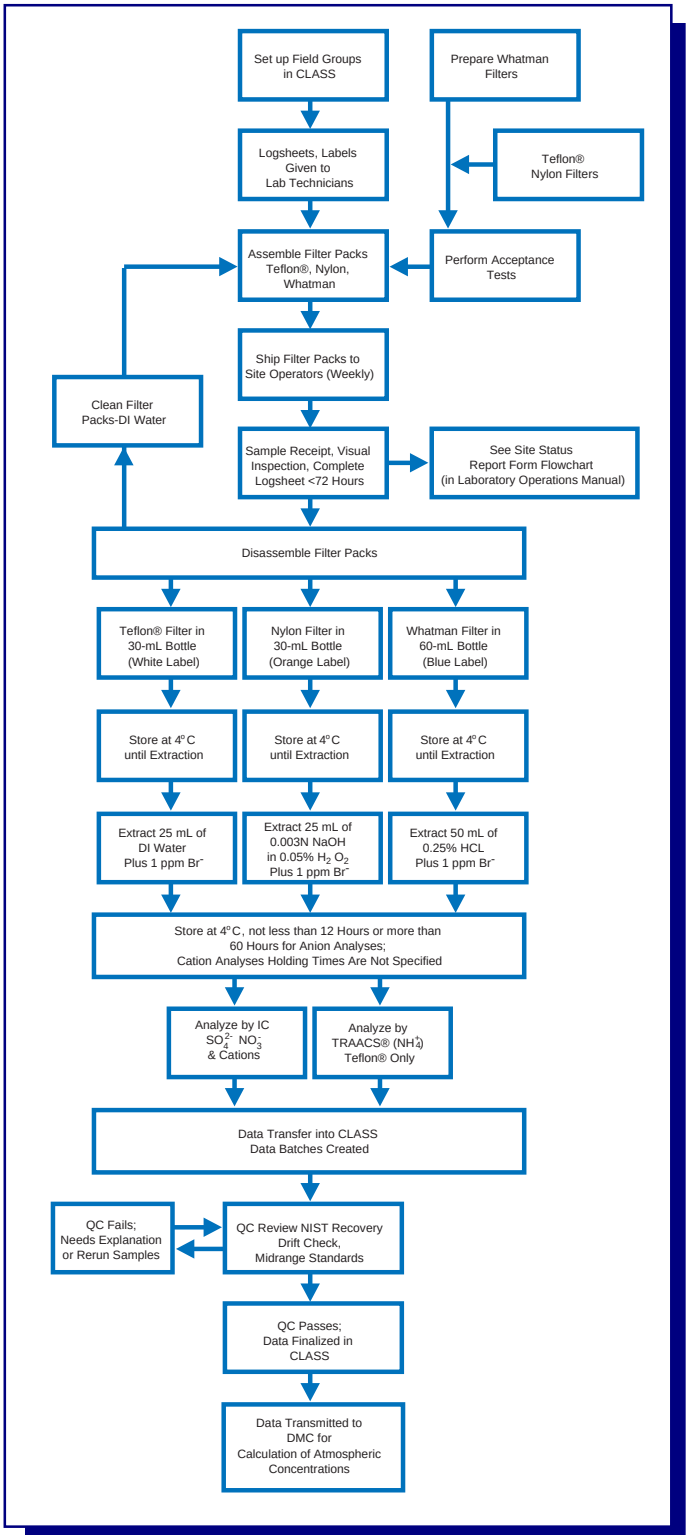


Figure 1-4. Flowchart of Laboratory Operations for Precipitation Sample Analyses

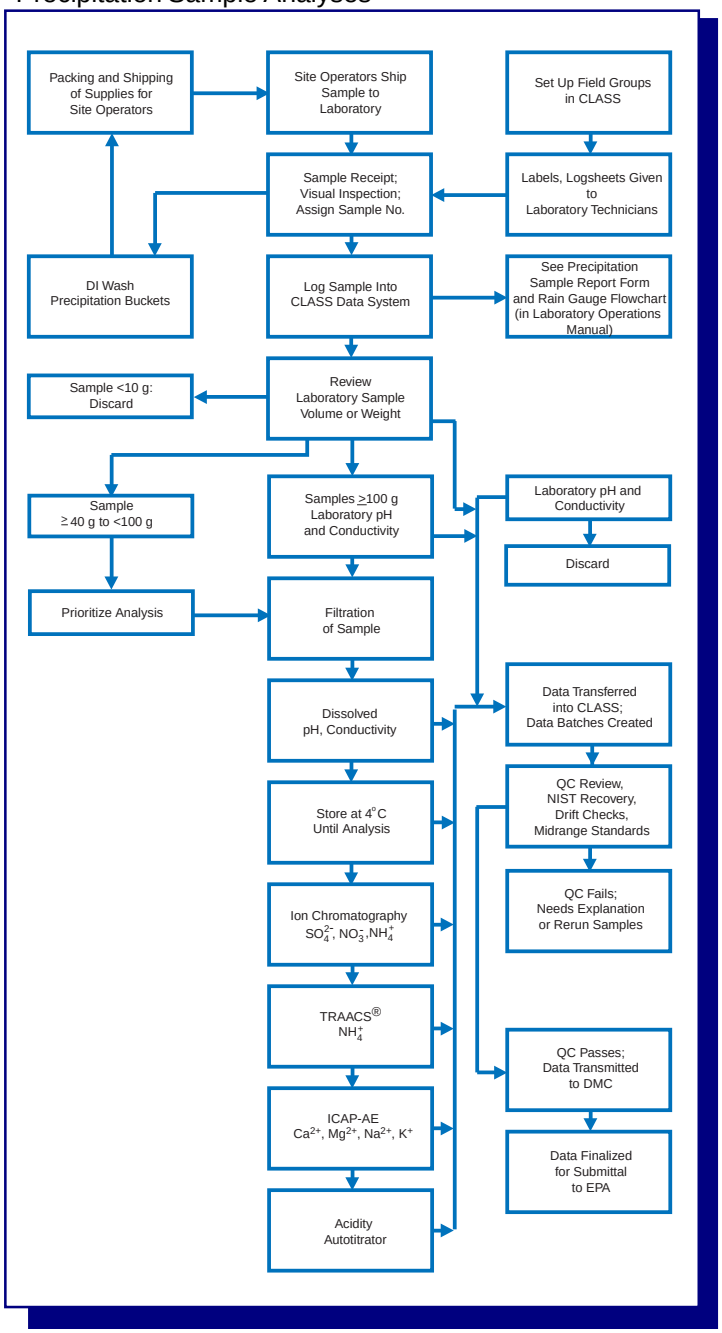
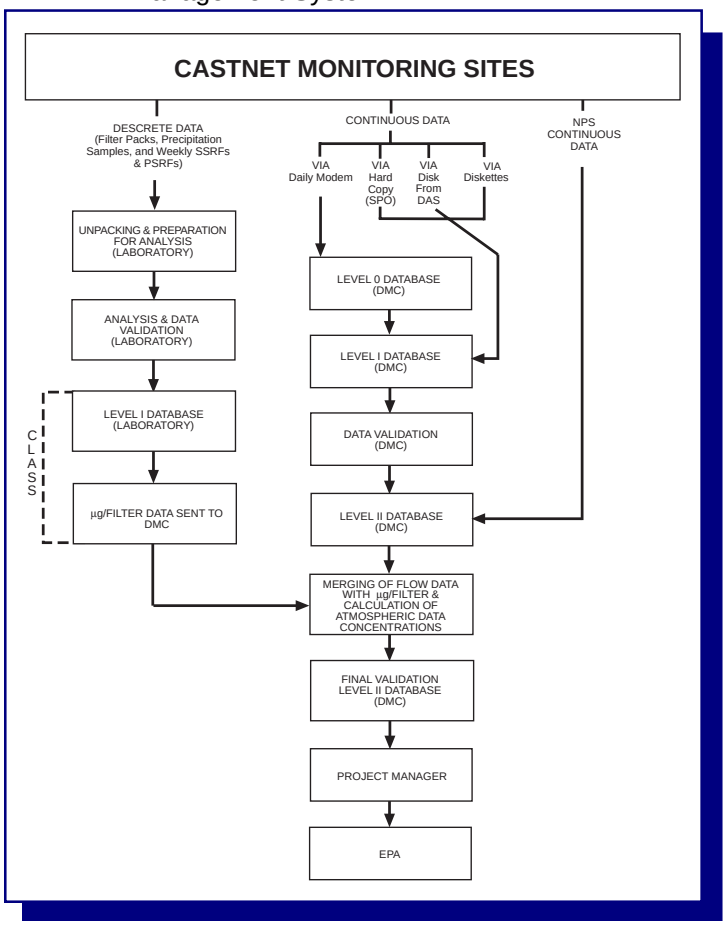


Figure 1-5. Flow of Data Through CASTNet Data Management System



an IBM-compatible PC and software developed by Odessa Engineering, Inc. The polling software enables recovery of hourly data and status files, power failure logs, and automated calibration results from the previous 7 days. The program also maintained synchronization of the network by checking the clock within each data acquisition system (DAS) and correcting the time if it deviated from expectation by more than 3 minutes. If daily polling resulted in incomplete data capture from any site, then diskettes of data from the primary and backup DAS were read into the database management system. If data were still incomplete, the missing data were entered manually either from site printouts or recovered from data cartridges. Each datum was automatically given a source flag that was used to trace its mode of entry into the system (i.e., modem, cartridge, or manual entry).

At each site, an Odessa DSM-3260 interfaced with a modem and printer constituted the primary DAS. An Odessa DSM-3260L was used as the backup DAS. The DAS collects and processes data from

the station sensors and instruments; averages, flags, and stores the data; transmits data upon command; and generates standard reports. Activation of the zero/span/precision sequence of the O_3 analyzer was also controlled by the DAS.

The onsite PC was used for communicating with the DAS and allowed the site operator to:

- Review hourly averages and instantaneous values,
- Review the status of initialization functions and control outputs, and
- Download data for transmittal to ESE.

Data were downloaded from the data cartridge to a disk that was mailed to ESE the first Tuesday of every month. A backup copy of the data was retained onsite. In addition, a dot-matrix printer provided a hard copy of hourly data and site operator interactions with the DAS. Printouts were sent to ESE weekly.

In summary, the continuous data were transmitted from CASTNet sites to the DMC via:

- Daily polling of each site by modem,
- A disk with hourly averages from the primary DAS,
- Hard-copy printouts, and
- A backup disk with hourly averages from the backup DAS.

The CASTNet database management system consists of a custom version of Odessa Engineering's Environmental Aide software. The Environmental Aide system consists of two programs, ENVICOM and ENVAID, which reside on a Local Area Network (LAN) in the DMC. ENVICOM is a communications and data transmittal package which polls each site daily and incorporates the previous day's hourly averages into the raw database. Data retrieved through ENVICOM were entered directly into the raw database and stored in binary data and status files. A Microsoft® Access™-based validation and data management system was used in 1998.

After daily polling of all stations, Level I validation procedures were initiated. Daily summaries were generated as data were collected from the sites. Field operations personnel then reviewed these reports daily to detect potential problems with minimal delay. Site Status Report Forms (SSRFs) and operator logsheets were reviewed weekly to verify the validity of the data received.

Level II validation involved a more detailed screening of the data. SSRFs, operator logsheets, calibration data, and audit results were reviewed for each site. In addition, data were screened using an automated program, which identified potential problems such as values greater than the expected range and invalid combinations of status flags, values, and spikes. All review and editing activities were documented.

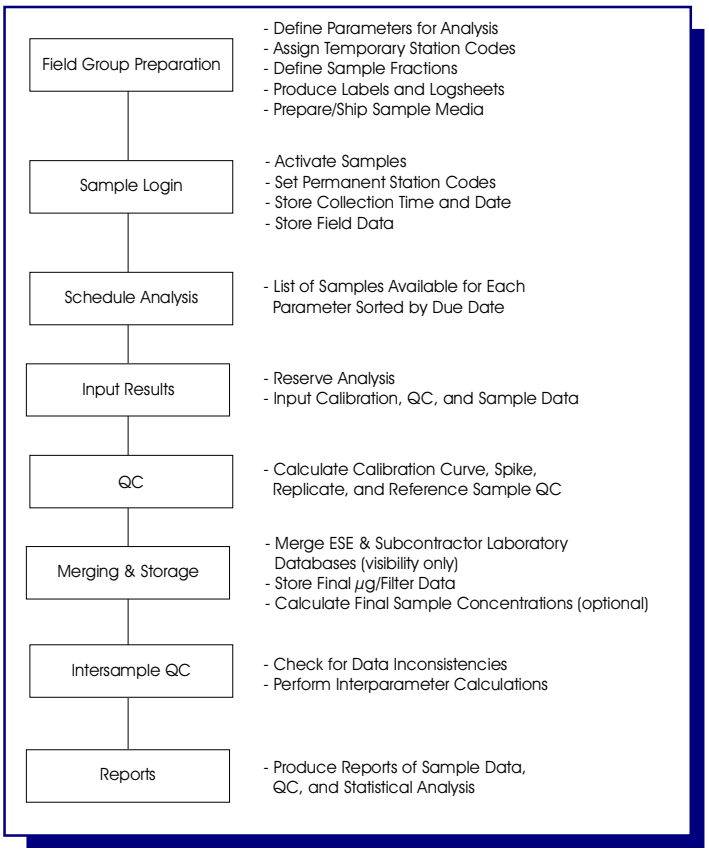
When all documentation was reviewed and the database was edited to the satisfaction of the Data Operations Manager, approximately 10% of the database was audited for traceability. Upon completion of the QA review, the database was verified as Level II.

All NPS continuous O_3 and meteorological data were received at Level II.

Laboratory Data

Data generated from filter pack and precipitation samplers (discrete data) were managed by CLASS™. Figure 1-6 depicts the flow of data management activities in CLASS™.

Figure 1-6. Flowchart of CLASS™ Program



Attainment of Level I validation for discrete data consisted of meeting the following criteria:

1. Data were determined to be reasonable based on the analyst's evaluation of the data batch QC sample results.
2. Data transfer by electronic or manual entry into CLASS™ was completed properly as evaluated by the Laboratory Operations Manager.
3. The appropriate analytical batches were processed through an automated QC checking routine performed by CLASS™ and

determined to be acceptable. For each analytical batch, a data flag was generated if any of the following occurred:

a. Insufficient QC data were run for the batch.
b. Correlation coefficient of standard curve was less than 0.995.
c. The 95% confidence limit of the Y-intercept exceeded the limit of quantitation.
d. Sample response exceeded the maximum standard response in the standard curve (i.e., the sample must be diluted to bring the response within the range of the curve).
e. Continuing verification samples (CVSs) exceeded the recovery limits.
f. Reference samples exceeded accuracy acceptance limit.

A batch with one (or more) flags was accepted only if written justification was provided by the Laboratory Operations Manager.

To calculate atmospheric concentrations from filter pack samples, filter pack flow data were merged with laboratory data at the DMC. Atmospheric concentrations were calculated only if valid hourly averages for filter pack flow represented at least 75% of the sampling period and analytical data met all QC criteria. Filter pack samples with greater than 75% but less than 90% valid flow data were flagged to indicate uncertainty in concentration calculations.

For wet deposition samples, a second laboratory data validation check involved two interparameter consistency checks:

1. Percent difference of cations versus anions, and
2. Percent difference of predicted-versus-measured conductivity.

CLASS™ has been programmed to calculate cations, anions, and predicted conductivity. Percent ionic and conductivity difference values are calculated by the following equation:

$$\textit{Percent difference} = 200 \times \frac{(V_1 - V_2)}{(V_1 + V_2)}$$

The criterion for re-analysis is:

1. Percent ionic difference of cations (Value 1) versus anions (Value 2):
   If pH <4.8, then criterion = ±15 percent
   If pH >4.8, then criterion = ±25 percent

2. Percent conductivity difference for predicted (Value 1) versus measured (Value 2) conductivity:
   If conductance <10, then criterion = ±25 percent
   If conductance >10, then criterion = ±10 percent

The evaluation of these interparameter consistency checks provided a method for determining whether the analysis should be repeated or verified.

Attainment of Level II validation required that:

1. All Level I data meeting QC criteria were reviewed and evaluated as acceptable by the Laboratory Operations Manager.
2. A review and evaluation of any data flags was completed by the Laboratory Operations Manager.
3. Written justification for acceptance of data that did not meet QC criteria was approved by the QA Supervisor.
4. The filter mass was provided to the DMC for calculating final filter pack concentrations.

The Multi-Layer Model

Again, model calculations of dry deposition rates (fluxes) are not presented in this report. However, a description of the MLM is given to illustrate the CASTNet approach to estimating dry deposition.

The original network design was based on the assumption that dry deposition or flux could be estimated as the linear product of ambient concentration (C) and deposition velocity (V_d):

$$\text{Flux} = \overline{C} \times \overline{V_d}$$

where the overbars indicate an average over a suitable time period (Chamberlain and Chadwick, 1953).

The influence of meteorological conditions, vegetation, and chemistry is simulated by V_d. Dry deposition processes are modeled as resistances to deposition (Myers *et al.*, 1998):

$$R = R_a + R_b + R_c = 1/V_d$$

R_a, the aerodynamic resistance, is inversely proportional to the atmosphere's ability to transfer material downward from the planetary boundary layer to the surface layer by turbulent processes. R_b is the boundary layer resistance to vertical transport (molecular diffusion) through a shallow (approximately 1 millimeter) nonturbulent layer of air in direct contact with the surface. R_b depends on the aerodynamics of the surface and the diffusivity of the pollutant being deposited. R_c, the canopy or surface uptake resistance, contains several terms (represented as parallel resistances) that account for the direct uptake/absorption of the pollutant by leaves, soil, other biological receptors within and below the canopy, and other surfaces such as rock and water. R_c contains parameterizations for vegetation type and density, solar radiation penetration of the canopy and wetness of the surface. R_c is difficult to treat theoretically, and the system of equations for estimating R_c is normally empirically adjusted based on direct observation of dry fluxes.

Using this physical and mathematical framework, two dry deposition models, Big Leaf and MLM, have been used to calculate dry deposition for CASTNet. Both models were developed by the NOAA Atmospheric Transport and Diffusion Division, Oak Ridge, TN. The Big Leaf model

treats the vegetation canopy as a one-dimensional surface. Big Leaf model results, aggregated to seasonal and annual averages for 1991, have been reported by Clarke and Edgerton (1993).

The MLM is a variation of the Big Leaf model wherein similar calculations are applied through a 20-layer canopy in which model parameters are modified by the redistribution of heat, momentum, and pollutants. The MLM requires the following input data: wind speed, wind direction, sigma theta, temperature, relative humidity, solar radiation, surface wetness, LAI, vegetative species and percent green leaf-out. The MLM also accounts for water and temperature stress as well as stomatal resistances of the vegetation and deposition to snow surfaces. Additionally, several parameters (e.g., soil resistance) have been modified in the MLM from those used in the Big Leaf model. Dry deposition calculations for the CASTNet sites are currently made using a version of the MLM updated in 1998.

The MLM was applied previously to simulate weekly depositions for the period 1987 to 1995. The results were reported in the CASTNet Deposition Summary Report (EPA, 1998). Since then, a few changes have been made to the model. The current model simulates variable soil moisture. The algorithm for the soil uptake resistance has been changed to account for the presence of snow or for the presence of certain crops and grasses. The minimum wind speed was changed from 0.2 to 0.1 m/sec and, if the relative humidity is above 89%, the surface wetness is set to 1.0.

The meteorological variables used to determine R_a and R_b were obtained from the 10-m meteorological tower at each of the sites, normally located in a clearing over grass or another low vegetative surface. Data on vegetative species and percent green leafout were obtained from site surveys and observations by the site operator. LAI measurements were taken during 1991, 1992 and 1997 at times of summer maximum. LAI values that are used in the MLM were extrapolated from these measurements using percent leafout observations. The resistance terms (R_a, R_b, and R_c) were calculated for each chemical species and major vegetation/surface type every hour. The V_d for a site was then calculated as the area-weighted V_d over vegetation types within 1.0 km of the site. Hourly V_d values and weekly integrated concentrations were used to produce hourly fluxes of HNO_3, SO_4^{2-}, NO_3^-, NH_4^+, and SO_2. O_3 flux was calculated using hourly O_3 measurements and hourly V_d values. Weekly flux calculations were considered valid if more than 75% of hourly V_d values were available for that week. Weekly values were aggregated to quarterly averages if 10 weeks in a quarter were valid. Quarterly averages were aggregated to annual only if three quarters were valid.

Data Delivery

Quarterly reports and data were submitted to EPA in ASCII format on a CD-ROM along with a hardcopy. Also provided to EPA were QC reports, listing parameter averages by site and aggregated counts of status flags. The quarterly data reports summarized network activities in the period and presented results of all field and laboratory QC checks.

The quarterly reports included maps of filter concentration data and aerosol data (including reconstructed fine mass). Trends analysis and time series plots were presented. O_3 concentrations were presented in terms of 1-hour and 8-hour concentrations.

Quality Assurance

The CASTNet QA audit program encompassed all major QC procedures depicted in Figure 1-7. A list of internal audits are categorized in Table 1-5. A detailed description of these audits can be found in the Draft CASTNet QAPP (ESE, 1999). The audit program was comprised of an internal QA program, an independent audit system, a corrective action and implementation system, and reporting procedures. The internal audits addressed all aspects of project operations, with the exception of field instrumentation performance audits. The latter component was managed and executed by ARS. Oversight was provided by the ESE field operations and QA staff.

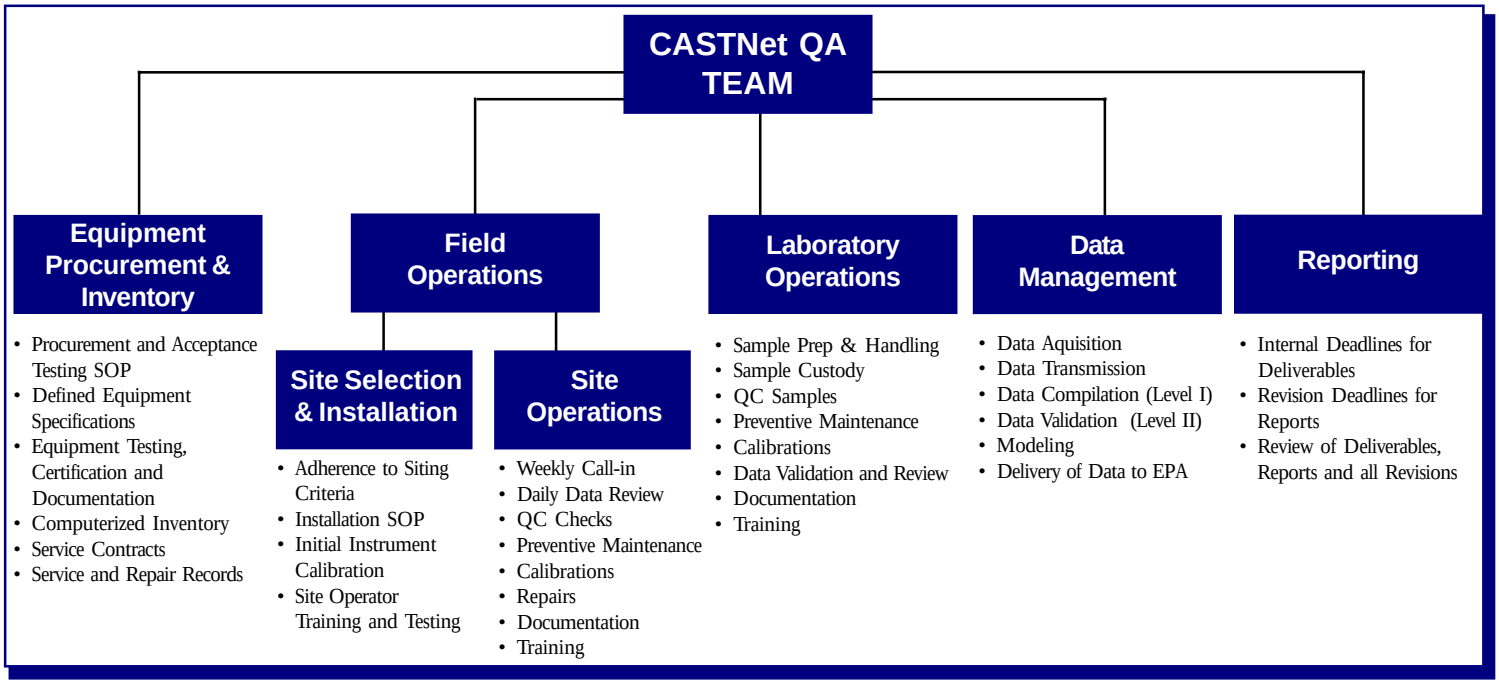
Table 1-5. Current Internal QA Audits

Audit	Frequency
Field Data	
Belfort Rain Gauge Chart	Quarterly
Belfort Calibration Data	Quarterly
Field Calibration Data	Quarterly
Level II Continuous Data Validation	Quarterly
Laboratory Data	
Filter Acceptance Results	Quarterly
Chain-of-Custody	Quarterly
Analytical Batch	Quarterly
Analytical QC Sample Results	Quarterly
Life History	Performed when new analysts begin and as needed
Combined Database	
Final Concentration Database	Quarterly

Internal Audits

Internal audits were conducted routinely on a quarterly basis. Additional audits were performed at the QA Supervisor's discretion and/or at the request of other project personnel. The routine audits traced approximately 10% of the data from their origin into the final validated database. The purpose of these audits was to verify that established protocols were followed, data quality was achieved and maintained, and

Figure 1-7. Overview of CASTNet QC Procedures by Task



updates to the database were performed correctly and documented accurately. Internal audits fall into the following categories:

- Field data audits,
- Laboratory data audits,
- Final combined database audits, and
- Subcontractor laboratory systems audits.

The subcontractor laboratories (used for analysis of aerosol parameters) are scheduled to be audited by the ESE QA staff during 1999. Results of QA activities are reported in monthly technical progress reports, quarterly reports, and reports to management.

Independent Audits

Independent systems and performance audits of each monitoring site were conducted annually by ARS. Results were submitted on a quarterly basis. A spot (quick-look) report for each site was faxed or E-mailed to the Field Operations Coordinator as soon as possible after each site audit to communicate findings. The quick exchange of information enables the Field Operations Coordinator to immediately correct conditions that may impact the ability to achieve or maintain data quality objectives (DQO) as well as document information for use during the data validation process. Descriptions of audit instrumentation and procedures are provided in External Quality Assurance Audit Guidance for CASTNet (ARS, 1997).

External Audits

External audits are audits conducted by the EPA or its designee. No external audits were performed in 1998.

Network History ($PM_{2.5}$ Aerosol/Visibility)

Visibility monitoring includes three measurement types as defined by the Interagency Monitoring of Protected Visual Environments (IMPROVE) program:

- Aerosol –Aerosol characteristics (concentration, composition, and size) are determined to relate atmospheric optical properties with various species.
- Optical–Optical properties (e.g., light scattering) of the atmosphere are monitored for a scene-independent measure of air quality.
- Scene –Visual characteristics (e.g., through photos) of a scene are monitored to document scene-specific visibility.

IMPROVE protocols were used to guide the CASTNet monitoring, instrument specifications, siting criteria, sample frequency, quality assurance, and analytical techniques.

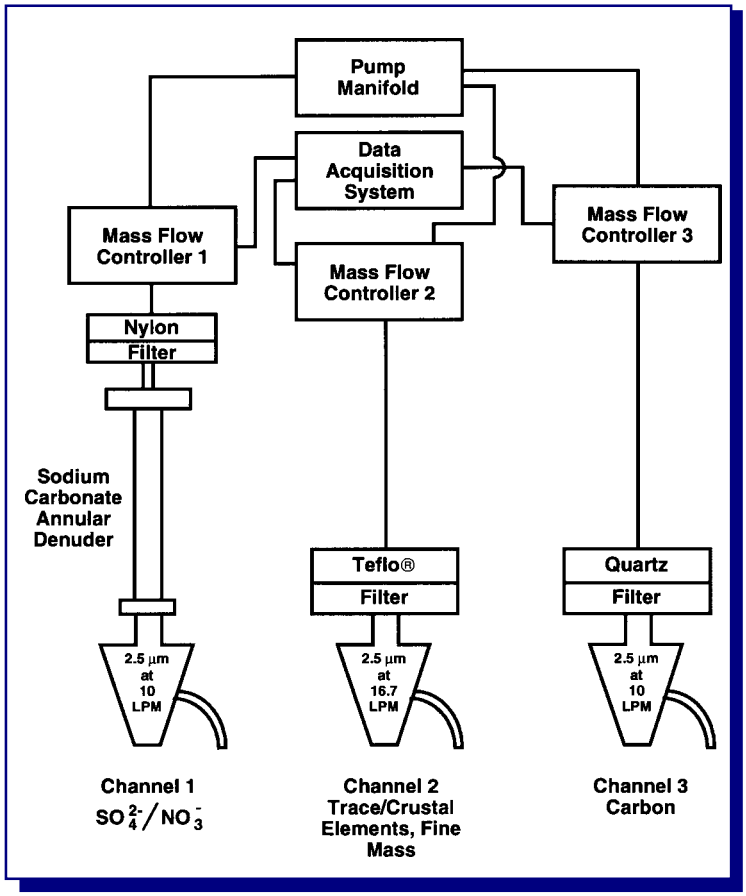
The 1998 CASTNet Visibility Network consisted of eight sites ranging from Louisiana to Illinois to New York. The locations of the

visibility sites were listed in Table 1-1. Figure 1-8 provides an independent depiction of the eight sites. The visibility sites have been operating since October 1993.

Figure 1-8. Locations of CASTNet Visibility Monitoring Sites

The CASTNet Visibility Network began collecting samples in 1993. These sites span throughout the eastern United States.

Figure 1-9. Aerosol Sampling System



Of the three measurement types, aerosol and light scattering measurements were taken during the 1998 sampling season (see Table 1-1). Photographs were not taken during 1998. All eight sites collected aerosol samples and two sites measured atmospheric light scattering. Aerosol sampling was conducted using time-integrated systems where 24-hour samples were collected every six days. Each aerosol sampling system consisted of three separate single-stage filter packs designated as denuder/nylon, Teflo®, and quartz (Figure 1-9). These designations refer to the type of filter media deployed in the respective filter pack.

The aerosol sampling system included independent flow channels for each of the three filter packs: two were operated at 10 Lpm, and one at 16.7 Lpm. All were equipped with mass flow controllers and located in a weather-proof enclosure at 10 meters above ground level. The channel for SO_4^{2-} and NO_3^- was operated at 10 Lpm and included a 2.5-micrometer (µm) cyclone, followed by a single base-impregnated (sodium carbonate) annular denuder tube and a single-stage nylon filter pack. The nylon filter was 47 millimeters (mm) in diameter. The trace/crustal elements and carbon channels included a 2.5-µm cyclone followed by a single-stage filter pack. Trace/crustal element samples and mass were collected on Teflo® filters [37mm diameter, with 16mm mask (25 mm deposit diameter)]. The use of the 16 mm mask was evaluated at Sikes. Its use was eliminated in January 1999. The Teflo® filter pack flowrate was 16.7 Lpm. Carbon samples were collected on precombusted quartz fiber filters (37mm diameter) at 10 Lpm.

As part of optical monitoring, nephelometers were used to measure atmospheric light scattering at two sites: Cadiz, KY (CDZ571) and Quaker City, OH (QAK572).

The CASTNet Visibility Network was initiated in October 1992. Measurements commenced in October 1993. Site surveys and report submittals for the four new installations (SIK570, CDZ571, QAK572, and LIV573) were completed between February 1993 and June 1993. The four new sites excluded sites that were used previously by CASTNet. In 1993, the visibility monitoring network originally

consisted of 10 sites, which has been reduced to eight sites since 1996 (see Table 1-1). The network history is summarized in Table 1-6.

Aerosol Sample Collection

From October 1993 through March 1994, aerosol samples were collected at all ten sites on a 3-day schedule. ALH557 (Alhambra, IL) was discontinued on March 30, 1994. The aerosol sample collection changed to 6-day schedule in August 1994 until present. Nine sites were operational from August 1994 through November 1995. All visibility network operations stopped on November 15, 1995, at the request of EPA. The network was reactivated in July 1996. SHN518 (Shenandoah National Park, VA) was not activated in July 1996 which reduced the network to its current configuration. SHN518 had been installed to develop comparability data (inter-network precision) with the IMPROVE network. This comparison study was operational from October 1993 through November 1995.

From February 1994 through November 1995, QAK572 was designated the collocated aerosol site to document intra-network sampling precision. Duplicate aerosol samples were collected on a 3-day schedule from February through July 1994. The collocated samples were collected on a 6-day schedule from August 1994 through January 1995. From February through November 1995, duplicate samples were collected on a 12-day schedule. SIK570 was designated as the collocated aerosol site when the network was reactivated in July 1996. SIK570 collected duplicate aerosol samples generally on a 12-day schedule during 1998.

During the third quarter 1998, the frequency of collocated sampling was increased to every 6 days. To evaluate the use of the 16 mm mask on the Teflo® filter, one system was operated with the mask and one system without the mask. The sampling frequency was then decreased back to 12 days during the fourth quarter; and the mask was used on both sampling systems. The mask was eliminated throughout the network at the beginning of 1999.

Optical Measurements

In July 1993 through August 1995, light scattering measurements were taken with Optec NGN-2 open-air integrating nephelometers at four sites: CTH510, ARE528, SIK570, and QAK572. Nephelometer operations at CTH510 and ARE528 ended in August 1995. Nephelometer operations at SIK570 and QAK572 were conducted until funding ended in November 1995. From October 1996 through 1997 nephelometers were operated at CDZ571 and QAK572.

Scene (Camera) Monitoring

Visual scene photographs began in June 1993 at CTH510 and ARE528. In July 1993, QAK572 began taking scene photographs.

Table 1-6. Summary of Visibility Network History

Date	Event
October 1992	Network planning began.
June 1993	Site surveys and site selection completed. Photographs began at CTH510 and ARE528.
July 1993	Nephelometers began operation at CTH510, ARE528, SIK570, and QAK572. Photographs began at QAK572.
October 1993	Aerosol measurements initiated at 10 sites, 24-hour samples every 3 days.
November 1993	Laboratory operations began at ESE, Desert Research Institute, and University of California at Davis.
February 1994	Collocated aerosol sampling at QAK572: February 1994 to July 1994, every 3 days; August 1994 to January 1995, every 6 days; and February 1995 to November 1995, every 12 days.
March 1994	ALH557 was discontinued.
August 1994	Sampling schedule changed to every 6 days.
January 1995	Sampling schedule at SHN518 changed to every other Saturday.
March 1995	Chester LabNet began analyzing Teflo® filters.
May 1995	Sunset Laboratory commenced analyzing quartz filters.
August 1995	Nephelometer measurements discontinued at CTH510 and ARE528. Photographs discontinued at CTH510 and QAK572.
November 1995	Network operations halted at the request of EPA. SHN518 was discontinued permanently.
July 1996	Network operations resumed at eight sites, collecting samples every 6 days. Nephelometer operations switched to CDZ571 and QAK572. Camera work was discontinued. SIK570 was selected for collocated sampling, collecting collocated samples every 12 days. Teflo® filter pack flowrates changed to 16.7 Lpm.
July 1998	The use of the 16 mm mask was evaluated at SIK570 during third quarter 1998. The mask was eliminated in January 1999.

The visual scene photographs were taken three times daily at 0900, 1200, and 1500 local standard time. Visual scene photographs at CTH510 and QAK572 ended in August 1995. ARE528 continued to take scene photographs until the November 1995 work stoppage. After November 1995, no visual scene photographs were taken.

Site History

In 1993, the CASTNet visibility sampling began at 10 locations (see Table 1-1). Six of the 10 sites were established at dry deposition sites, which were retrofitted with visibility instrumentation. Four new visibility sites were established in 1993. Conventional dry deposition sampling (filter pack, O_3, and meteorology) was established at two (QAK572 and CDZ571) of the new sites. The siting criteria for the visibility sites included the requirements for regional representativeness that was used for most dry deposition sites plus an additional requirement for nearby scenic vistas, which could be photographed to document visual characteristics of a scene.

ALH557 and SHN518 were discontinued on March 30, 1994, and November 15, 1995, respectively, reducing visibility to the current eight-site network.

CTH510 — Connecticut Hill, NY

CTH510 is a dry deposition site retrofitted with visibility instrumentation. On June 28, 1993, Air Resource Specialists, Inc. (ARS) installed the nephelometer and began collecting data on July 1, 1993. The camera system was installed on June 28 and began taking photographs on June 29, 1993. ARS operated the nephelometer and camera until August 31, 1995.

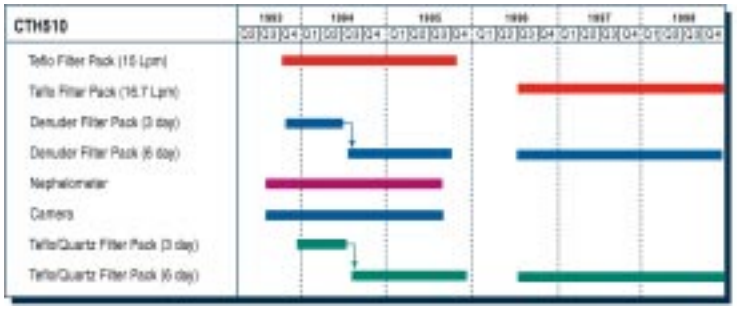
ESE installed the aerosol system on September 21, 1993. Sample collection from the nylon filter pack began on October 1, 1993. Sample collection from the Teflo® and quartz filter packs began on December 3, 1993. Initially, aerosol samples were collected on a 3-day schedule and were then switched to a 6-day schedule on August 1, 1994.

As part of the aerosol system, ESE interfaced the MFCs with a DAS. The DAS was initialized to record meteorological, nephelometer, and aerosol flow data. The visibility DAS was used as a backup to the dry deposition DAS.

On November 15, 1995, CTH510 operations were stopped at the request of EPA.

On June 20, 1996, ESE performed multipoint calibrations on the aerosol system. Aerosol sampling began on July 8, 1996. From December 3, 1993 through November 15, 1995, the Teflo® filter pack flowrate was 15.0 Lpm. During the June 20, 1996 calibration, the Teflo® filter pack flowrate was changed to 16.7 Lpm to conform to manufacturer specifications. All Teflo® samples from July 8, 1996 throughout 1998 were collected with flowrates of 16.7 Lpm.

Throughout 1998, CTH510 collected aerosol samples on a 6-day schedule. The nephelometer and camera systems have been removed from the site since August 1995.



MKG513 — M.K. Goddard State Park, PA

MKG513 is a dry deposition site retrofitted with visibility instrumentation. ESE installed the aerosol system on September 18, 1993. Sample collection from the nylon filter pack began on October 31, 1993. Sample collection from the Teflo® and quartz filter packs began on December 3, 1993. Initially, aerosol samples were collected on a 3-day schedule and were then switched to a 6-day schedule on August 1, 1994.

As part of the aerosol system, ESE interfaced the MFCs with a DAS. The DAS was initialized to record meteorological and aerosol flow data. The visibility DAS was used as a backup to the dry deposition system.

On November 15, 1995, MKG513 operations were stopped at the request of EPA.

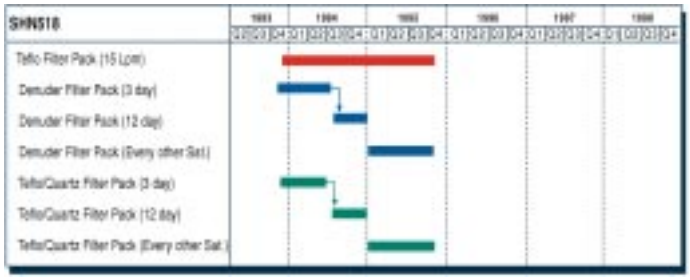
On June 28, 1996, ESE performed multipoint calibrations on the aerosol system. Aerosol sampling began on July 8, 1996. From December 3, 1993 through November 15, 1995, the Teflo® filter pack flowrate was 15.0 Lpm. During the June 28, 1996 calibration, the Teflo® filter pack flowrate was changed to 16.7 Lpm. All Teflo® samples from July 8, 1996 throughout 1998 were collected with flowrates of 16.7 Lpm.

In 1998, MKG513 collected aerosol samples on a 6-day schedule. The DAS for MKG513 collected meteorological data as a backup to the dry deposition system, and also collected the integrated aerosol flow data.

SHN518 — Shenandoah National Park, VA

The purpose for establishing a visibility site at SHN518 was to develop aerosol comparability data (inter-network precision) with the IMPROVE network sampler. ESE installed the aerosol system on October 18, 1993. Sample collection from the nylon filter pack began on November 9, 1993. Sample collection from the Teflo® and quartz filter packs began on December 6, 1993. The Teflo® filter flowrate was 15.0 Lpm for the duration of the sampling. Initially, aerosol samples were collected on a 3-day schedule. From August 1, 1994 through December 31, 1994, aerosol samples were collected on a 12-day schedule. From January 1, 1995 through November 4, 1995, aerosol samples were collected every other Saturday only.

SHN518 was not re-activated after the November 15, 1995 work stoppage.



ARE528 — Arendtsville, PA

ARE528 is a dry deposition site retrofitted with visibility instrumentation. On June 26, 1993, ARS installed the nephelometer and began collecting data on July 1, 1993. The camera system was installed on June 26 and started taking photographs on June 28, 1993. ARS operated the nephelometer through August 31, 1995. The camera continued to take photographs until November 15, 1995.

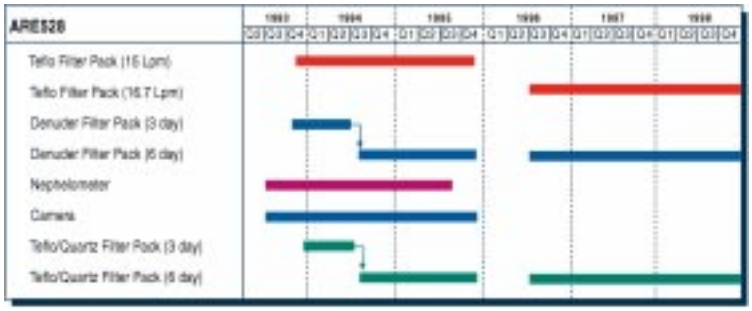
ESE installed the aerosol system on September 16, 1993. Sample collection from the nylon filter pack began on October 1, 1993. Sample collection from the Teflo® and quartz filter packs began on December 3, 1993. Initially, aerosol samples were collected on a 3-day schedule and were then switched to a 6-day schedule on August 1, 1994.

As part of the aerosol system, ESE interfaced the MFCs with a DAS. The DAS was initialized to record meteorological, nephelometer, and aerosol flow data. The visibility DAS was used as a backup to the dry deposition system.

On November 15, 1995, ARE528 operations were stopped at the request of EPA.

On July 8, 1996, ESE performed multipoint calibrations on the aerosol system. Aerosol sampling began on July 14, 1996. From December 3, 1993 through November 15, 1995, the Teflo® filter pack flowrate was 15.0 Lpm. During the July 8, 1996 calibration, the Teflo® filter pack flowrate was changed to 16.7 Lpm. All Teflo® samples from July 14, 1996 throughout 1998 were collected with flowrates of 16.7 Lpm.

Throughout 1998, ARE528 collected aerosol samples on a 6-day schedule. The nephelometer and camera systems have been removed from the site since November 1995. The DAS for ARE528 collected meteorological data as a backup to the dry deposition system, and also collected the integrated aerosol flow data.



BVL530 — Bondville, IL

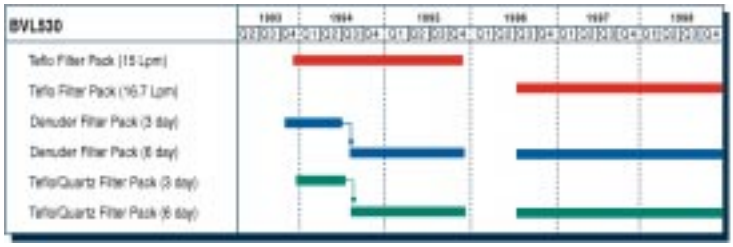
BVL530 is a dry deposition site retrofitted with visibility instrumentation. ESE installed the aerosol system on September 24, 1993. Sample collection from the nylon filter pack began on October 7, 1993. Sample collection from the Teflo® and quartz filter packs began on December 3, 1993. Initially, aerosol samples were collected on a 3-day schedule and were then switched to a 6-day schedule on August 1, 1994.

As part of the aerosol system, ESE interfaced the MFCs with a DAS. The DAS was initialized to record meteorological and aerosol flow data. The visibility DAS was used as a backup to the dry deposition system.

On November 15, 1995, BVL530 operations were stopped at the request of EPA.

On July 9, 1996, ESE performed multipoint calibrations on the aerosol system. Aerosol sampling began on July 26, 1996. From December 3, 1993 through November 15, 1995, the Teflo® filter pack flowrate was 15.0 Lpm. During the July 9, 1996 calibration, the Teflo® filter pack flowrate was changed to 16.7 Lpm. All Teflo® samples from July 26, 1996 throughout 1998 were collected with flowrates of 16.7 Lpm.

Throughout 1998, BVL530 collected aerosol samples on a 6-day schedule. The DAS for BVL530 collected meteorological data as a backup to the dry deposition system, and also collected the integrated aerosol flow data.

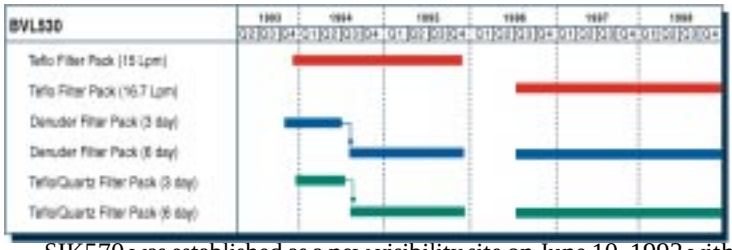


ALH557 — Alhambra, IL

ALH557 has not collected aerosol samples since March 30, 1994.

ALH557 was a dry deposition site retrofitted with visibility instrumentation. ESE installed the aerosol system on September 19, 1993. Sample collection from the nylon filter pack began on October 7, 1993. Sample collection from the Teflo® and quartz filter packs began on December 9, 1993. The Teflo® filter flowrate was 15.0 Lpm throughout the sampling period. The aerosol samples were collected on a 3-day schedule through March 30, 1994. ALH557 discontinued collecting aerosol samples on March 30, 1994. The visibility aerosol sample system was removed from the site on June 21, 1994 after completion of the final multipoint calibration.

SIK570 — Sikes, LA



SIK570 was established as a new visibility site on June 10, 1993 with the initial calibration of the meteorological instrumentation, nephelometer, and dry deposition sample system. The meteorological instrumentation included wind direction, wind speed, temperature, delta temperature, relative humidity, precipitation (tipping bucket), solar radiation, and wetness. Nephelometer data collection did not begin until July 27, 1993, due to telephone line problems preventing data telemetry.

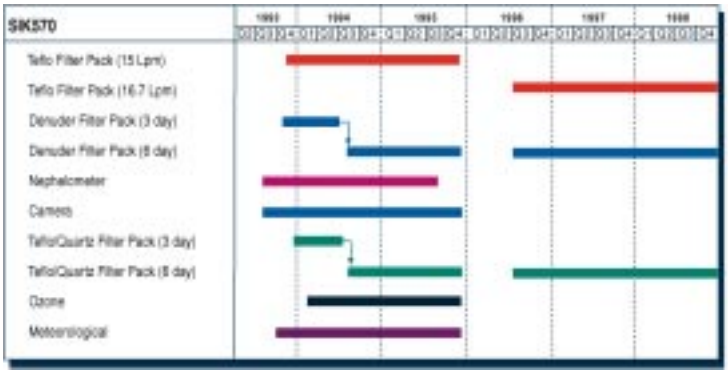
On September 9, 1993, ESE installed the aerosol sampling system at which time the dry deposition sample system was removed from SIK570. Due to DAS limitations, the dry deposition and visibility aerosol sample systems could not be operated simultaneously. Sample collection from the nylon filter pack began on October 1, 1993. Sample collection from the Teflo® and quartz filter packs began on December 9, 1993. Initially, aerosol samples were collected on a 3-day schedule and were then switched to a 6-day schedule on August 1, 1994.

ESE installed an ozone (O_3) analyzer at this site on February 11, 1994 with DAS interface through November 15, 1995.

On November 15, 1995, SIK570 operations were stopped at the request of EPA. The meteorological instrumentation, O_3 monitor, and nephelometer were not operated at SIK570 after November 1995.

On July 7, 1996, ESE performed multipoint calibrations on the primary aerosol system. Also, a collocated aerosol sampling system was installed. Aerosol sampling began on July 8, 1996, and collects samples on a 12-day schedule.

From December 3, 1993 through November 15, 1995, the Teflo® filter



pack flowrate was 15.0 Lpm. During the July 7, 1996 calibration, the Teflo® filter pack flowrate was changed to 16.7 Lpm. All Teflo® samples from July 8, 1996 throughout 1998 were collected with flowrates of 16.7 Lpm.

In 1998, SIK570 collected aerosol samples on a 6-day schedule. The collocated system collected aerosol samples on a 12-day schedule.

CDZ571 — Cadiz, KY

CDZ571 was established as a new visibility and dry deposition site on August 23, 1993, with the initial calibration of the meteorological instrumentation, O_3 analyzer, and dry deposition sample system. The meteorological instrumentation included wind direction, wind speed, temperature, delta temperature, relative humidity, precipitation (tipping bucket), solar radiation, and wetness. The meteorological instrumentation, O_3 monitor, and the dry deposition sampling system were interfaced with the DAS through November 1995.

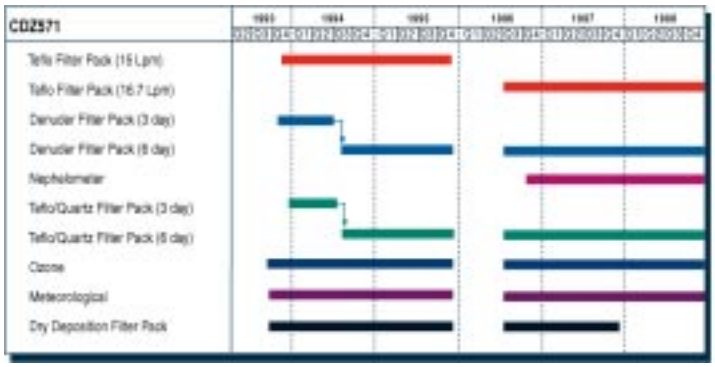
On September 19, 1993, ESE installed the aerosol sampling system. Sample collection from the nylon filter pack began on October 1, 1993. Sample collection from the Teflo® and quartz filter packs began on December 6, 1993. Initially, aerosol samples were collected on a 3-day schedule and were then switched to a 6-day schedule on August 1, 1994.

On November 15, 1995, CDZ571 operations were stopped at the request of EPA.

On June 29, 1996, ESE performed calibrations on all instrumentation at CDZ571 which included meteorological equipment, O_3 monitor, dry deposition sample system, and visibility aerosol sample system. Aerosol sampling began on July 8, 1996. Dry deposition sampling continued after the work stoppage through November 4, 1997.

ARS installed a nephelometer on September 16, 1996. Nephelometer data collection was delayed until October 15, 1996, because of electrical surge damage to the nephelometer. The damage to the nephelometer occurred on September 17, 1996.

From December 3, 1993 through November 15, 1995, the Teflo® filter pack flowrate was 15.0 Lpm. During the June 29, 1996 calibration, the Teflo® filter pack flowrate was changed to 16.7 Lpm. All Teflo® samples from July 8, 1996 throughout 1998 were collected with flowrates of 16.7 Lpm.



In 1998, CDZ571 collected aerosol samples on a 6-day schedule. Collection of meteorological data and measurement of O_3 concentrations and atmospheric scattering coefficients continued through 1998. Dry deposition samples were collected through November 1997 and were re-initiated in January 1999.

QAK572 — Quaker City, OH

QAK572 was established as a new visibility and dry deposition site on July 23, 1993 with ARS installing the nephelometer and camera systems. Photographs were taken on July 24 and collection of nephelometer data began July 25, 1993. The camera system was operational through August 31, 1995. The nephelometer was operational through November 15, 1995. ARS installed and calibrated the nephelometer on October 1, 1996. Data collection also began on October 1, 1996.

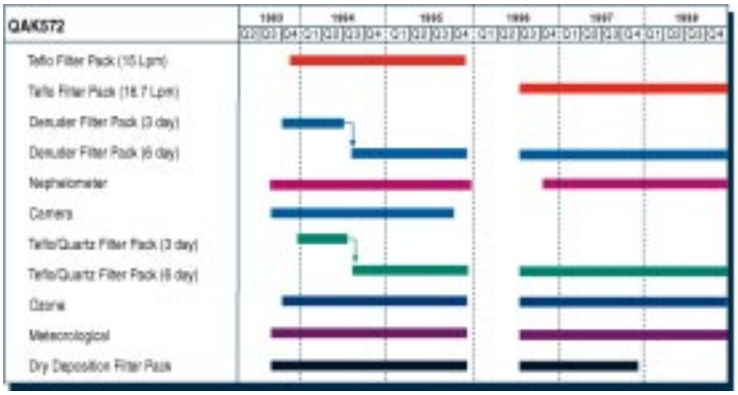
On July 24, 1993, ESE performed the initial calibration of the meteorological instrumentation and dry deposition sample system. The meteorological instrumentation included wind direction, wind speed, temperature, delta temperature, relative humidity, precipitation (tipping bucket), solar radiation, and wetness.

On September 17, 1993, ESE installed the aerosol sampling system and O_3 monitor. O_3 measurements began on September 17, 1993. Sample collection from the nylon filter pack began on October 1, 1993. Sample collection from the Teflo® and quartz filter packs began on December 18, 1993. ESE installed a collocated aerosol sampling site (designated QAK272) on December 10, 1993. Collection of collocated aerosol samples began on February 2, 1994. Initially, both the primary and collocated aerosol samples were collected on a 3-day schedule. From August 1, 1994 through Janaury 31, 1995, both primary and duplicate samples were collected on a 6-day schedule. From February 1, 1995 through November 15, 1995, duplicate samples were collected on a 12-day schedule.

On November 15, 1995, QAK572 operations were stopped at the request of EPA. After November 1995, the collocated aerosol sampling was discontinued.

On July 13, 1996, ESE performed multipoint calibrations on the aerosol sampling system. The Teflo® filter pack flowrate was changed to 16.7 Lpm. Aerosol sampling began July 26, 1996. From December 18, 1993 through November 15, 1995, the Teflo® filter pack flowrate was 15.0 Lpm. All Teflo® samples from July 26, 1996 to present have been collected with flowrates of 16.7 Lpm.

On July 27, 1996, ESE performed calibrations on the meteorological



instruments, O_3 monitor, and dry deposition sampling system. The dry deposition sampling system was operational through November 4, 1997.

In 1998, QAK572 collected aerosol samples on a 6-day schedule. Meteorological data and measurement of O_3 concentrations and atmospheric scattering coefficients were also collected. Dry deposition measurements were re-initiated in January 1999.

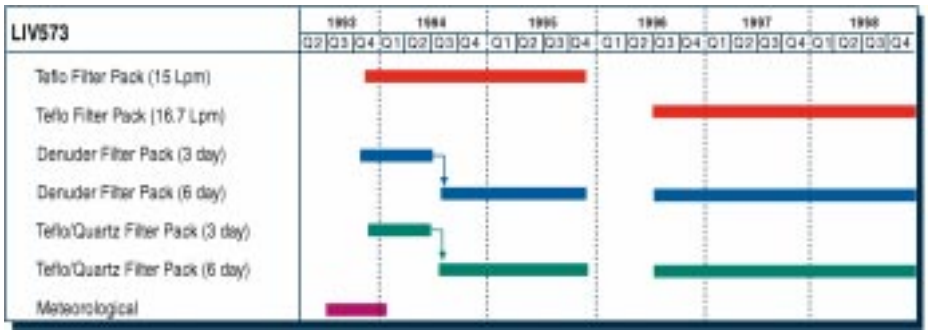
LIV573 — Livonia, IN

LIV573 was established as a new visibility site on July 13, 1993 with the initial calibration of the meteorological instrumentation. The instrumentation included wind direction, wind speed, temperature, delta temperature, relative humidity, precipitation (tipping bucket), solar radiation, and wetness. Operation of the meteorological instrumentation was discontinued on January 26, 1994.

On September 21, 1993, ESE installed the aerosol sampling system. Sample collection from the nylon filter pack began on October 7, 1993. Sample collection from the Teflo® and quartz filter packs began on December 3, 1993. Initially, aerosol samples were collected on a 3-day schedule and were then switched to a 6-day schedule on August 1, 1994.

On November 15, 1995, LIV573 operations were stopped at the request of EPA.

On July 12, 1996, ESE performed multipoint calibrations on the aerosol sampling system. Aerosol sampling began on July 26, 1996. From December 3, 1993 through November 15, 1995, the Teflo® filter pack flowrate was 15.0 Lpm. During the July 12, 1996 calibration, the Teflo® filter pack flowrate was changed to 16.7 Lpm. All Teflo® samples from July 26, 1996 to present have been collected with flowrates of 16.7 Lpm.



In 1998, LIV573 collected aerosol samples on a 6-day schedule.

Methods

Field Operations

In 1998, 24-hour integrated aerosol samples were collected on a 6-day schedule at eight visibility sites (CTH510, MKG513, ARE528, BVL530, SIK570, CDZ571, QAK572, LIV573). Denuders were changed out on the same 6-day schedule. Duplicate samples were collected on a 12-day schedule at SIK570 (except during the third quarter) to document intra-network sampling precision. Optec NGN-2 open-air integrating nephelometers were operated at CDZ571 and QAK572 during 1998.

Meteorological data were collected at CDZ571 and QAK572 in support of the nephelometer operations. In addition to the meteorological data, O_3 concentrations were measured at CDZ571 and QAK572 during 1998. Conventional dry deposition sampling was conducted at CDZ571 and QAK572 until November 1997 and again in January 1999.

Laboratory Operations

From 1993 to 1998, ESE's laboratory analyzed SO_4^{2-} and NO_3^- on the nylon filters. From 1993 through April 30, 1995, Desert Research Institute (DRI) analyzed organic and elemental carbon on quartz filters. University of California at Davis (UCD) analyzed mass, absorbance, and trace/crustal elements on Teflo® filters from 1993 through February 28, 1995. Since May 3, 1995, Sunset Laboratory has analyzed organic and elemental carbon on quartz filters. Since March 4, 1995, Chester LabNet has analysed mass and trace/crustal elements on Teflo® filters.

After every third sampling event, the denuders, nylon, Teflo®, and quartz filters were shipped to the ESE laboratory from each visibility site. Each month, the ESE laboratory shipped valid Teflo® and quartz samples to Chester LabNet and Sunset Laboratory, respectively.

The ESE laboratory extracted the nylon filters, and

then the nylon extracts were analyzed for NO_3^- and SO_4^{2-} by micromembrane suppressed ion chromatography (IC).

Quartz filters were analyzed by Sunset Laboratory for elemental and organic carbon using thermal-optical analysis (TOA). The TOA method is based on the principle that organic and elemental carbon react under different temperature and oxidation conditions. Previously, DRI used a similar method to measure carbon on quartz filters.

Teflo® filters are analyzed by Chester LabNet for mass (gravimetry) and the elements sodium (Na) through lead (Pb) by X-ray fluorescence (XRF). The analysis of elements by XRF uses a Kevex Model 771 spectrometer with electronic and computer software upgrades.

Previously, UCD used proton-induced x-ray emissions (PIXE) and XRF to analyze for the elements Na through Pb. In addition, UCD used proton elastic scattering analysis (PESA) to measure hydrogen and the laser integrating plate method (LIPM) to estimate light absorption.

Mass is determined generally following protocols (e.g., filter equilibration) based on EPA 40 Code of Federal Regulations (CFR) 50, Appendix L. Filters are acceptance-tested in a laminar flow hood and tare-weighted on a Cahn Model 31 microbalance under computer control. Tare-weighted filters are shipped to the field in individual plastic petri slides with snap lids. After exposure in the field, filters are gross weighted on the same balance, and deposit net weights are calculated from the difference in the gross and tare weights. All gravimetry operations are performed in a temperature-(21± 3°C) and humidity- (40 ± 5% relative humidity) controlled environment.

Data Management

Visibility data are managed cooperatively by ESE and ARS. Continuous field data from nephelometers and temperature and relative humidity sensors are acquired by the ESE Data Management Center (DMC) and relayed to ARS daily. ESE validates aerosol data, and ARS validates b_{scat} data. Following validation, all b_{scat} data and associated documentation are transferred to the CASTNet DMC at ESE. Data are delivered to EPA quarterly.

Quality Assurance

The CASTNet visibility sites operate according to the procedures described in the draft CASTNet QAPP (ESE, 1999). The QAPP is the guiding document for implementation of all deposition monitoring.

The quality assurance (QA) program was designed to achieve certain requirements for precision and accuracy that were negotiated with EPA. The goal for accuracy is 5% for SO_4^{2-} and NO_3^- and 10% for the other analytes. Accuracy was determined by analyzing a NIST reference sample at the beginning and end of each analytical batch. The goals for precision are 10% for SO_4^{2-}, NO_3^- and fine mass; 15% for b_{scat}; and 20% for the trace and crustal elements. Precision of the aerosol measurements was determined by calculating the median absolute percent difference of the collocated data collected at the Sikes, LA site. Precision of the nephelometer data was calculated by analyzing the zero/span calibration checks.